Investigation of Interactions Between Co-fired LTCC Components

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PURPOSE OF THE PRESENTATION

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- To present the results of thick-film resistor (TFR) properties measured in co-fired LTCC (**L**ow **T**emperature **C**o-fired **C**eramic) structures

- To determine the effects of paste properties and processing conditions on properties

- To interpret the results using charac-terization tools such as SEM, EDXS analysis, dilatometry

AN OVERVIEW

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→ Integration of thick-film pastes into LTCC sheets increases reliability concerns

→ Reliablility depends strongly on the physical and chemical compatibility of different components fired together

→ The challenges at this critical point has to be well-understood and controlled

APPLICATION EXAMPLES

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OUTLINE OF THIS PRESENTATION

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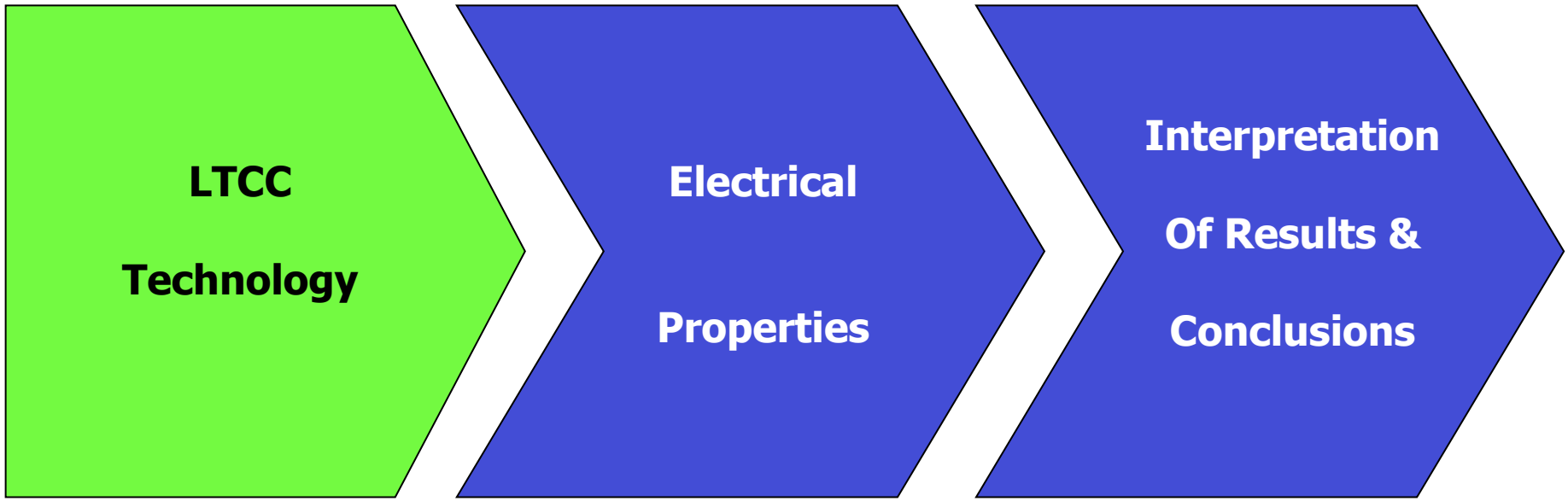

→Introduction

→Advantages

→Challenges

→Preparation of test patterns

→Properties
- TCR
- Sheet resistance

→Compatibility
- Physical issues
- Chemical issues

→Conclusions

WHAT IS LTCC TECHNOLOGY?

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Based on LTCC tapes of various thicknesses which

- sinter below 900°C
- are glass ceramics with excellent dielectric properties
- are screen-printed and co/post-fired with thick-film electronic passive components

LTCC MATERIALS SYSTEM

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	COMPONENTS		
	SUBSTRATE	PASSIVES	
Components	**Tape**	**Conductor**	**Resistor**
Function	Dielectric layer	Thick-film paste	Thick-film paste
Functional group	Dielectric powder	Precious metal, fine size powder	Conductive oxide, fine size powder
Glass	✍ Lowers T_{firing}, ✍ increases dielectric strength and density	✍ Lowers T_{firing}, ✍ increases adhesion to substrate and density	✍ Lowers T_{firing}, ✍ increases density ✍ surrounds conductive powder
Organics	Binder, solvent, dispersant for appropriate rheology		

ADVANTAGES OF LTCC TECHNOLOGY AT A GLANCE

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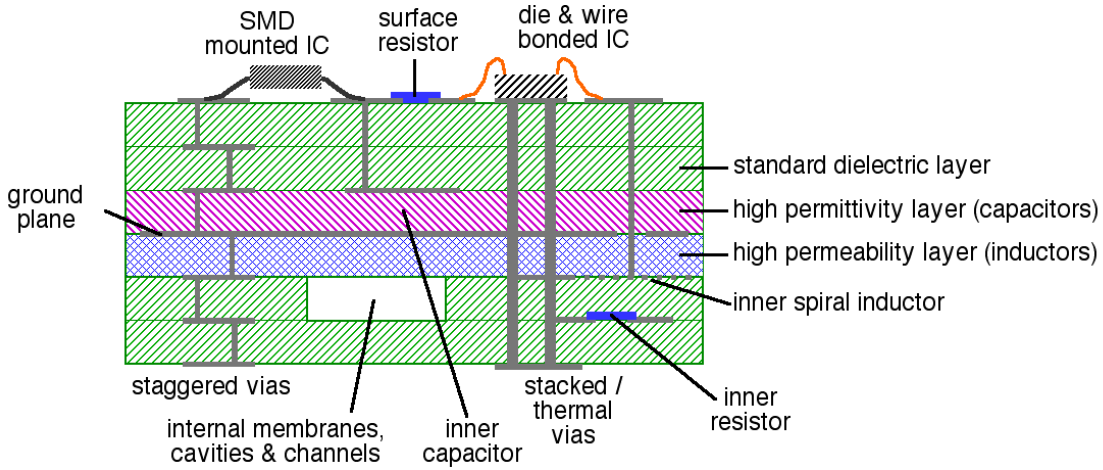

- Excellent dielectric properties for high frequencies
- Ease of machinability of tapes
- Cost effective
- High density packaging
- Excellent chemical / thermal stability
- Hermeticity of the structures
- Mechanical and electrical functions in one system

CHALLENGES

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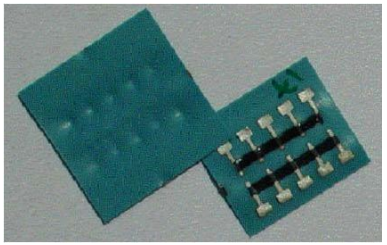
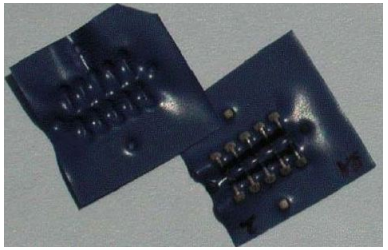
1. Physical Issues

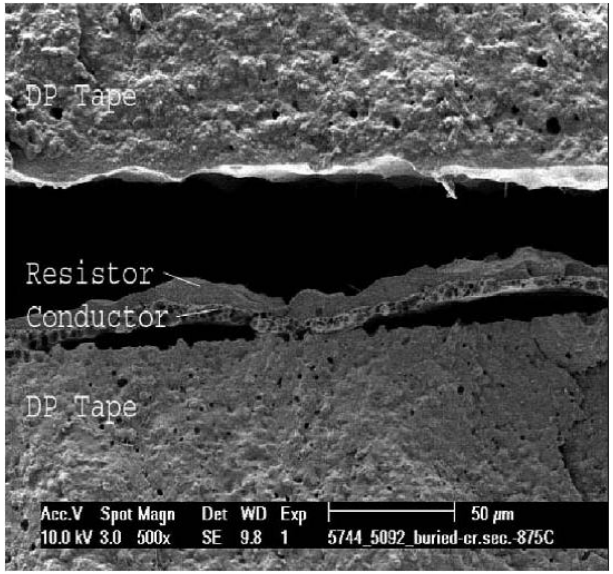
→ differential shrinkage

→ degassing

→ lamination







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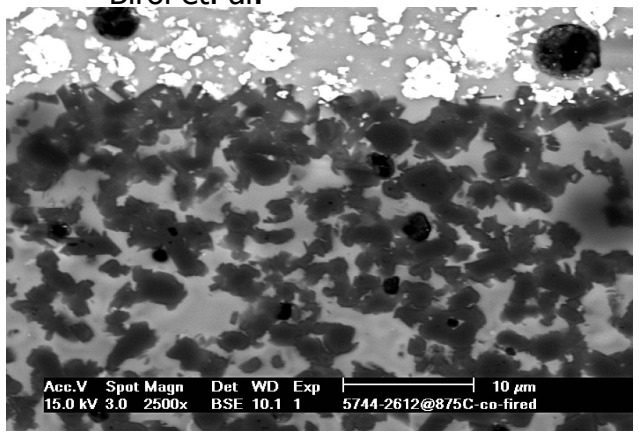
2. Chemical Issues

→ Interaction of components

→ Oxidizing /reducing conditions



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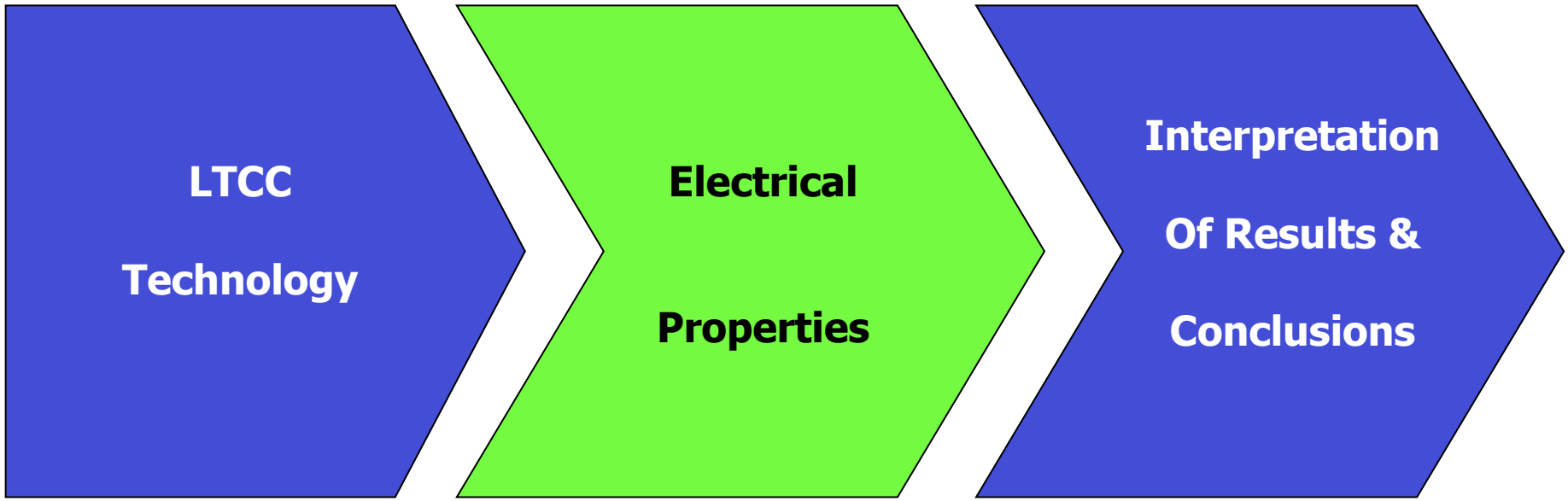

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PREPARATION OF TEST PATTERNS

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Function	Commercial Product	Chemical Origin	Specification
Substrate	DuPont (DP) 951-AX LTCC Tape	Glass-ceramic	254µ-thickness
Conductor	ESL 8837	Au	Organo-metallic
	DP 5744	Au	Classic
Resistor	DP 5092 D	Ru-based	R_s = 100Ω / □ at 25°C TCR = 2400 ppm/K

Firing method	Screen-printing	Drying	Lamination	Firing (heating cycle)
Co-fired	+	+		+
Buried	+	+	+	+

Heating Cycle

STEP1: 25°C → 440°C
5°C/min, t_{dwell} = 120min

STEP2: 440°C → T_{firing}
5°C/min, t_{dwell} = 25min

STEP3: T_{firing} → 25°C
10°C/min

→ Au-based conductors selected

(they are observed to result in less deformation on tapes compared to other compositions such as Ag/Pd, Ag/Pd/Pt, Pt)

PROPERTIES

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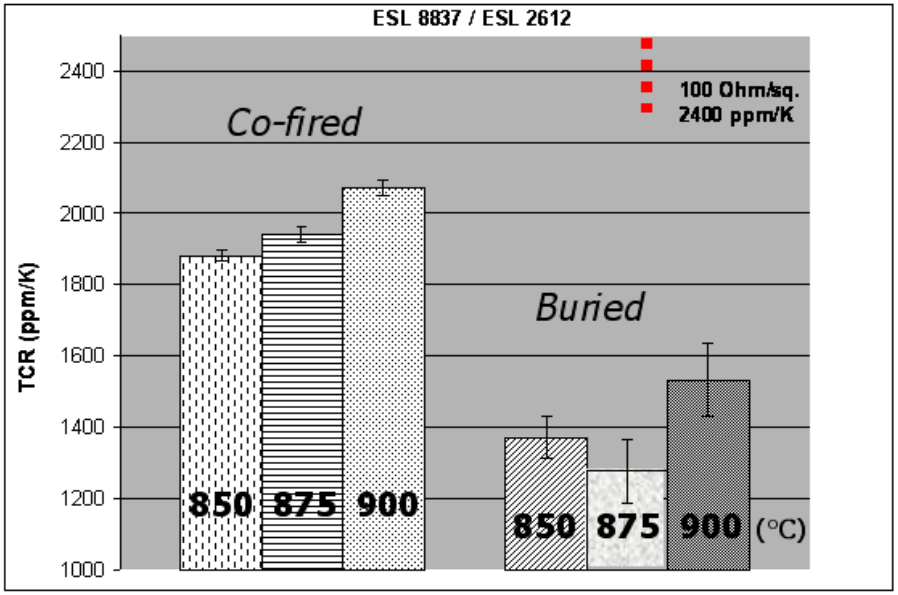
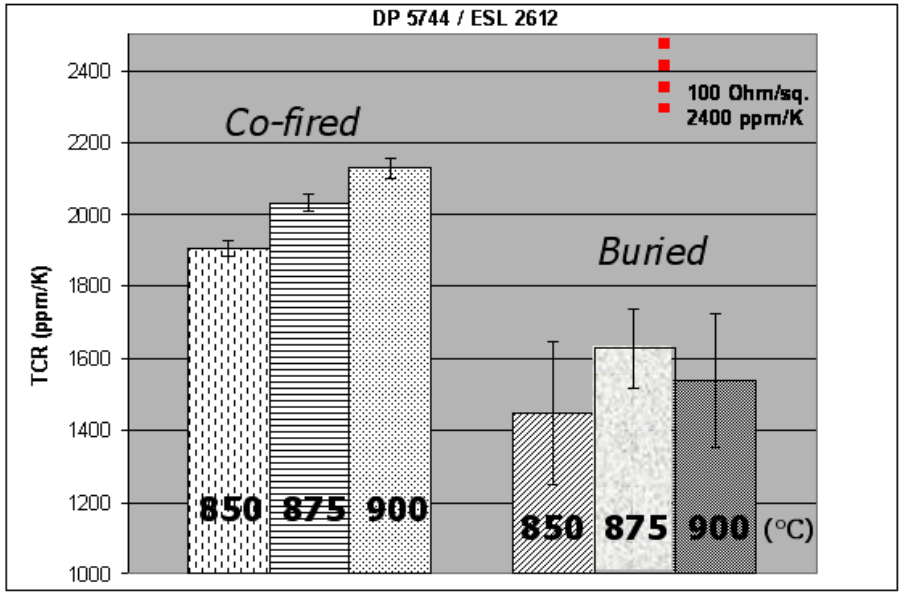
TEMPERATURE COEFFICIENT OF RESISTANCE (TCR)





Co-fired Samples ⇒
- fall in a TCR range close to producer-specified values
- standard deviation is very small

Buried Samples ⇒
- non-reproducible TCR values
- standard deviation is very big

PROPERTIES SHEET RESISTANCE

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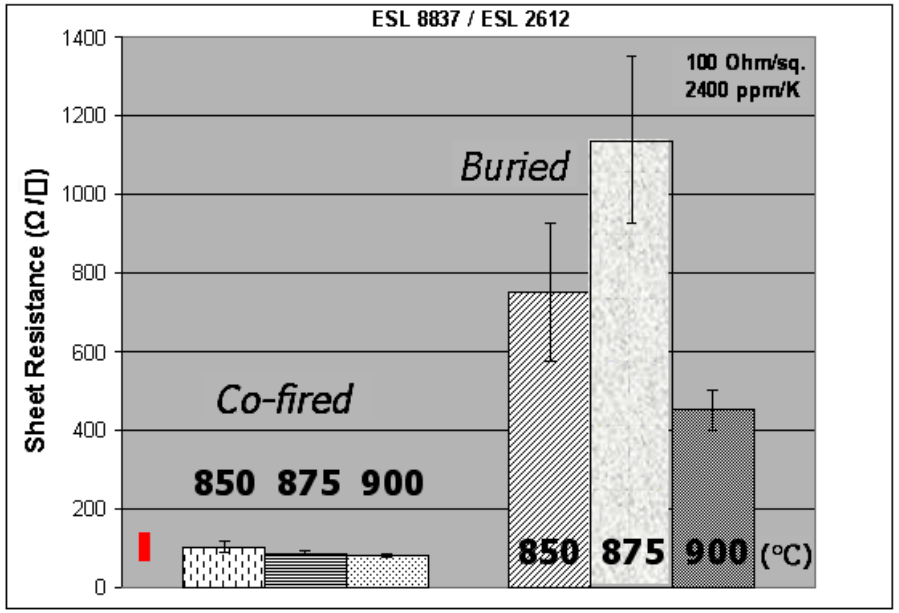

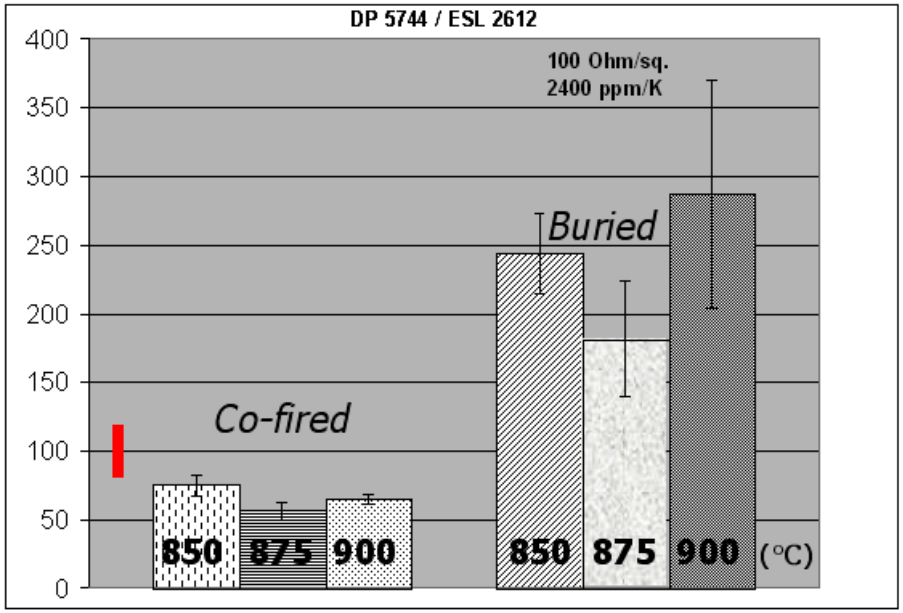

Co-fired Samples ⇒
- close to producer-specified values
- standard deviation is small

Buried Samples ⇒
- non-reproducible sheet resistance values *(particularly for ESL 8837)*
- standard deviation is very big

OUTLINE OF THIS PRESENTATION

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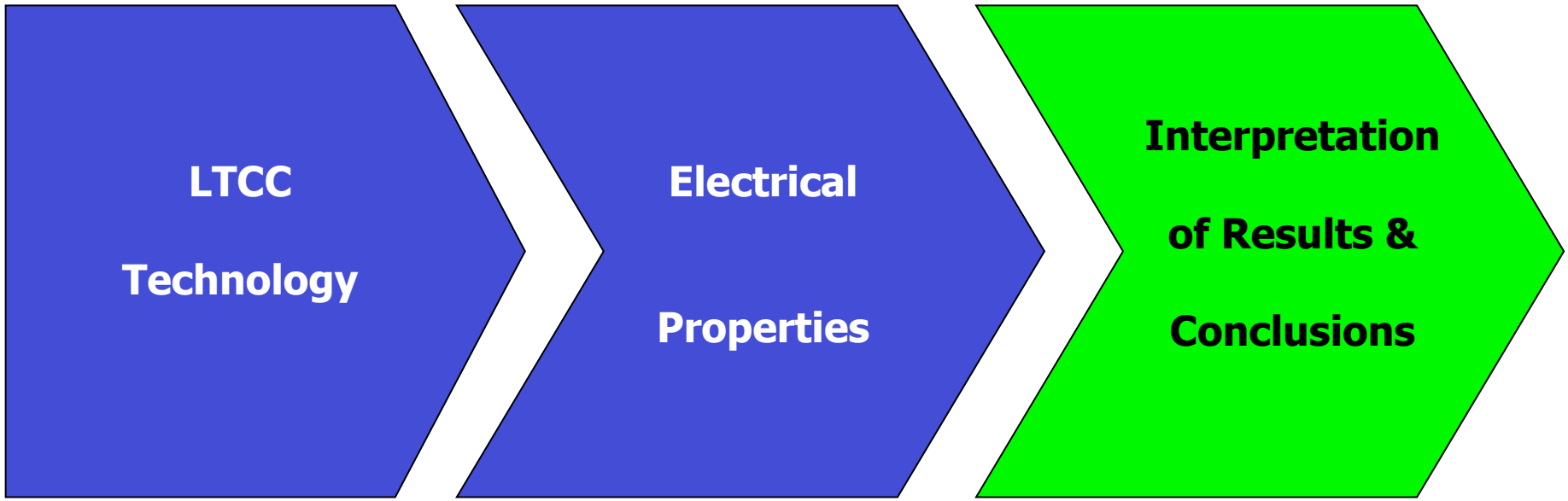

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COMPATIBILITY OF COMPONENTS

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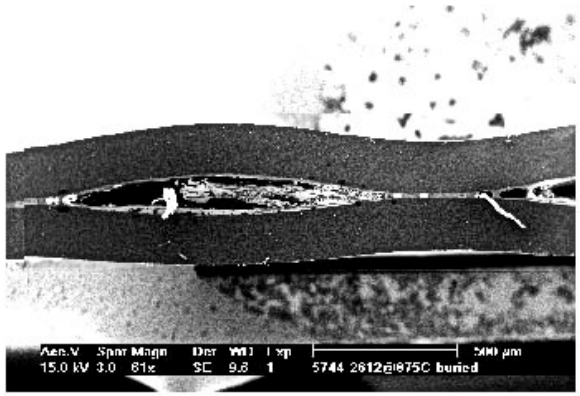
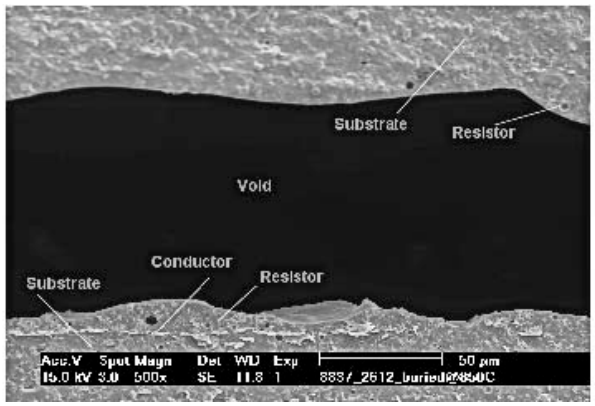
A. Physical Issues

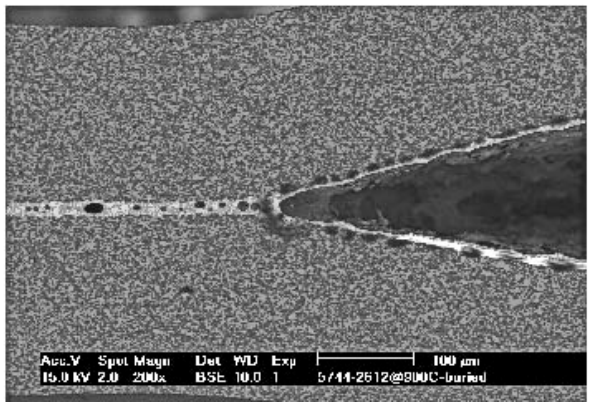
Buried structures fired at 850°C



Conductor – Resistor



Cavity due to entrapped gases



Conductor-Resistor

⇨ Deformation of the structure due to entrapped gases after burn-out of organics in the pastes *(at contacts)*.

Delamination of component layers at contacts resulting in termination problems particularly for short resistors

COMPATIBILITY OF COMPONENTS

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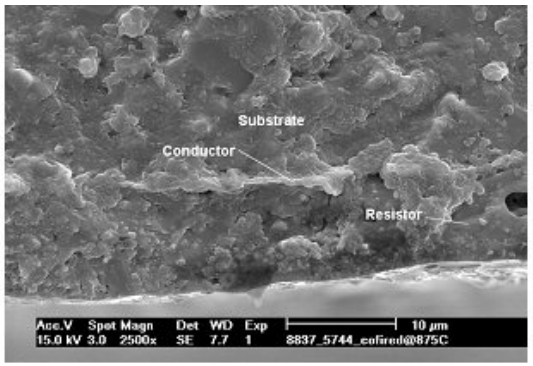
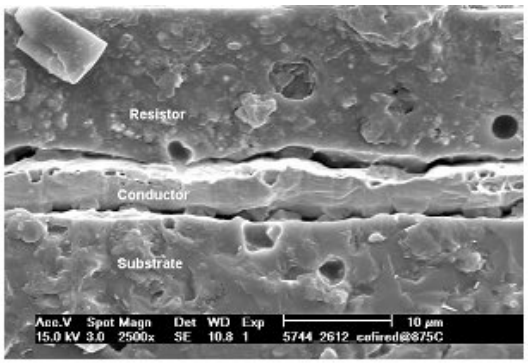
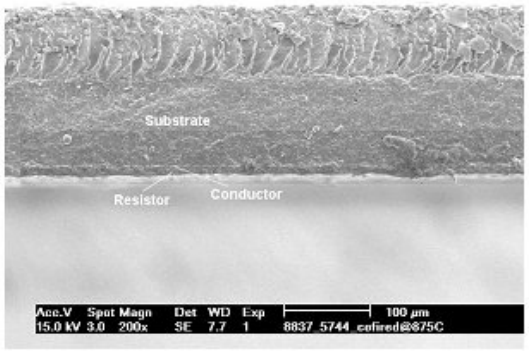
Co-fired structures using different conductor pastes at 850°C

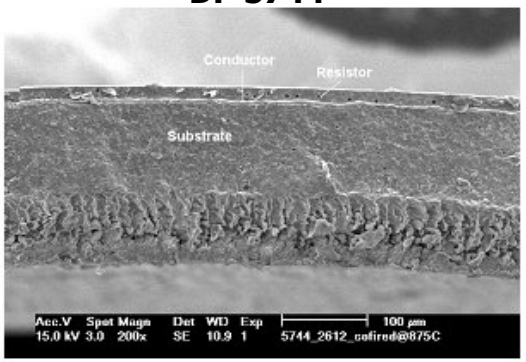


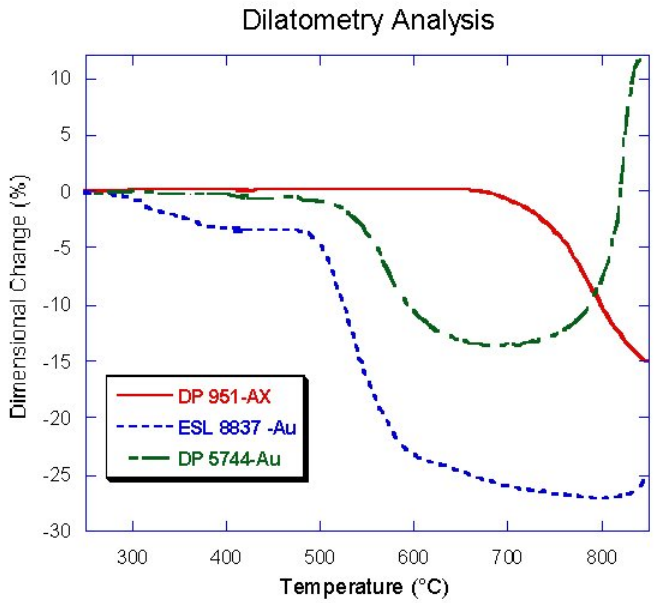
ESL 8837



DP 5744







$\Rightarrow t_{fired}$ (DP 5744-Au) > t_{fired} (ESL 8837-Au)

$\Rightarrow$ Expansion of DP 5744-Au conductor after 700°C

Increased deformation in DP 5744-Au used-samples during co-firing

COMPATIBILITY OF COMPONENTS

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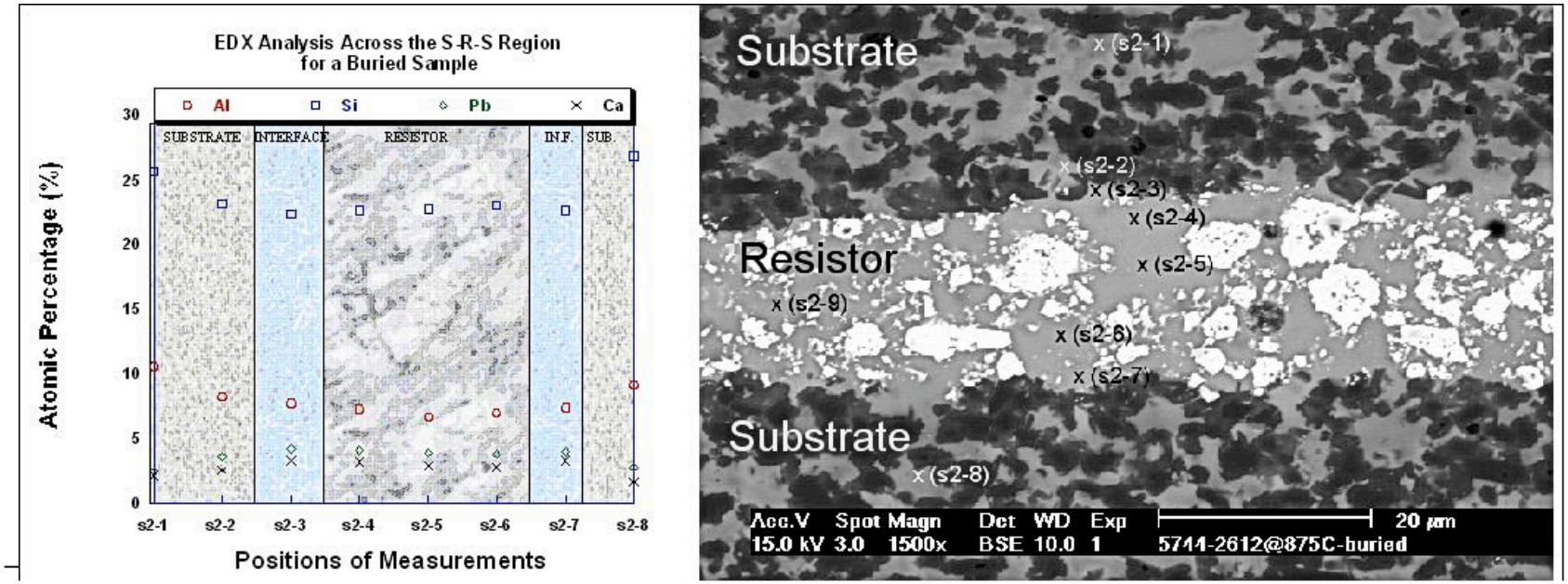
B. Chemical Issues

Chemical analysis by EDXS across the substrate-resistor-substrate region of a buried sample



⇨ Concentration of certain elements show a distribution over the interfaces between components

Indicator for formation of new phases, which directly affects the properties

COMPATIBILITY OF COMPONENTS

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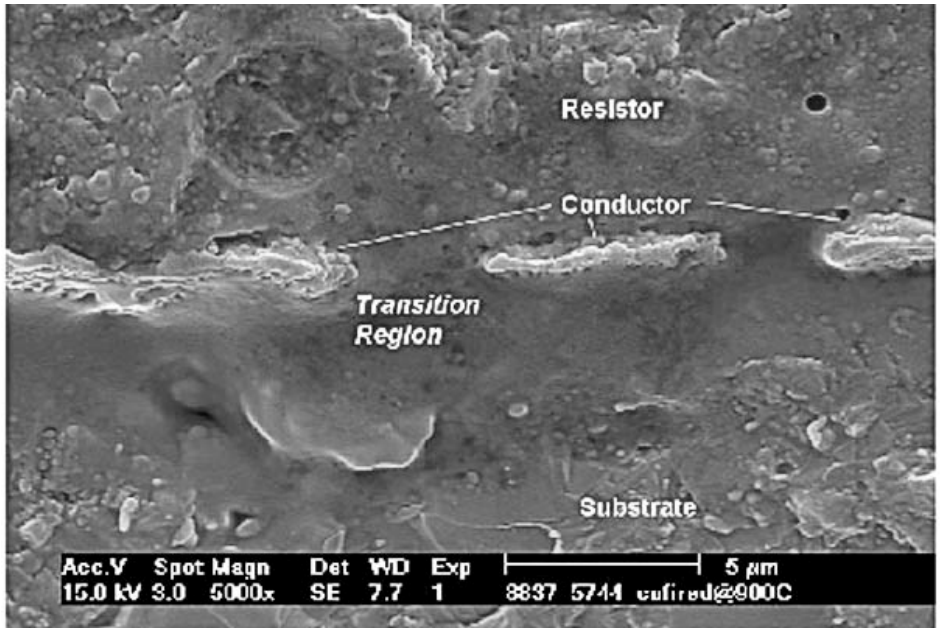

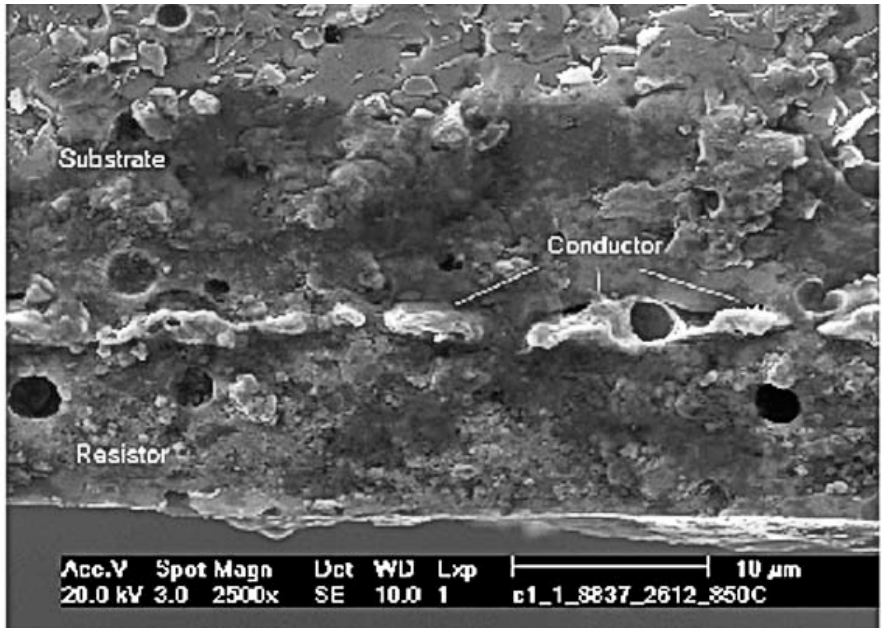

⇨ Glass additive, which is mobile at T_G , is observed to migrate easily between components.

(Porosity within the components, fine thicknesses enhance this effect)

CONCLUSIONS

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- Processing parameters are to be yet optimized for buried firing.
- Differential shrinkage, printed paste thickness, chemical interaction are pointed to be the main cause of unreliability.
- Selected pastes cannot be totally considered compatible.

NEXT STEPS

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- Improving processing conditions
- Better understanding the nature of the components being used and their reactions to varying processing parameters
- Matching of the components' sintering behavior to that of the tape
- More analysis on the chemical interactions between the components